

CLAIMS

What is claimed is:

1. A unilateral fixator comprising:
 - a strut assembly, having a proximate end and a distal end;
 - a first compound movable joint attached to the proximate end of the strut assembly having a first revolute joint with a first axis and a second revolute joint with a second axis;
 - a second compound movable joint attached to the distal end of the strut assembly having a third revolute joint with a third axis and a fourth revolute joint with a fourth axis; and
 - a bone fragment attachment apparatus attached to each of the first and second compound movable joints.
2. The device of claim 1 wherein the first axis and second axis are orthogonally opposed and the third axis and the fourth axis are orthogonally opposed.
3. The device of claim 1 wherein the first compound movable joint is capable of rotating about the linear axis of the strut assembly and the second compound movable joint is capable of sliding along the linear axis of the strut assembly.
4. The device of claim 1 wherein each of the revolute joints comprises a gear reduction mechanism.

5. The device of claim 4 wherein the gear reduction mechanism comprises an axial helical spline mechanism.

6. The device of claim 4 wherein the gear reduction mechanism comprises a concentric helical spline mechanism.

7. The device of claim 4 wherein the gear reduction mechanism comprises

- a left-hand helical spline;
- a right-hand helical spline;
- a thrust washer positioned between the right-hand helical spline and the left-hand helical spline;
- a helical spool, wherein the helical spool slides within the right-hand helical spline and the left hand helical spline and is rotationally engaged to the right-hand helical spline and the left hand helical spline; and
- a cap screw axially clamping together the left-hand helical spline, the right-hand helical spline, and the thrust washer and allowing for a fine adjustment of the reduction mechanism while the bone fragment attachment apparatus is engaged with a bone fragment.

8. The device of claim 4 wherein the gear reduction mechanism comprises:

- a knob adjuster;
- a drive shaft;
- a bearing supporting the drive shaft;
- an Oldham disk having a tongue that engages a slot on the drive shaft;
- a gear having a slot that engages a tongue on the Oldham disk;
- a cam; wherein the cam has a circular cross section having an axis that is eccentric from the axis of rotation and controls the radial alignment of the gear;
- a lock knob, wherein the cam is affixed to the lock knob and a movement of the lock knob causes a movement of the cam; and
- a housing comprising internal gear teeth having the same pitch as the external gear teeth of the gear and the number of internal gear teeth of the housing exceeds the number of external gear teeth of the gear.

9. The device of claim 1, wherein the strut assembly comprises:

- a base strut; and
- an extension strut; wherein the extension strut moves linearly within the base strut.

10. The device of claim 9, wherein the base strut further comprises a square key inserted into a milled slot and the extension strut further comprises a groove able to receive the square key to prevent the base strut and extension strut from rotating relative to each other.

11. The device of claim 10 wherein the extension strut further comprises a linear adjuster, a threaded rod and a solid, threaded locking insert, wherein the linear adjuster is connected to the base strut and the threaded rod, the threaded rod is also connected to the Solid, threaded locking insert which is connected to the extension strut.

12. The device of claim 11 wherein when the linear adjuster is rotated, the extension strut moves linearly within the base strut.

13. The device of claim 1 wherein the bone fragment attachment apparatus comprises a pin clamp and one or more pins.

14. The device of claim 1 wherein the first and second compound movable joints each comprise a plurality of locking devices, wherein one or more of the locking devices restricts one of the degrees of freedom associated with each compound movable joint.

15. The device of claim 14 wherein each of the locking devices comprises at least one cap screw, wherein the cap screw secures a housing containing the gear reduction mechanism to allow for the gross positioning of the first compound movable joint and the second compound movable joint.

16. A unilateral fixator comprising:
- a strut; having a proximate end and a distal end;
 - a first compound movable joint attached to the proximate end of the strut having a first revolute joint with a first axis, a second revolute joint with a second axis, and a third revolute joint having a third axis;
 - a second compound movable joint attached to the distal end of the strut having a fourth revolute joint with a fourth axis and a fifth revolute joint and a fifth axis, wherein the fourth axis and the fifth axis are orthogonally opposed; and
 - a bone fragment attachment apparatus attached to each of the first and second compound movable joints.
17. The device of claim 16 wherein the first axis, the second axis, and the third axis are orthogonally opposed to each other and the fourth axis and the fifth axis are orthogonally opposed to each other.
18. The device of claim 16 wherein the first compound movable joint is fixed relative to the strut and the second compound movable joint is capable of moving along the linear axis of the strut.
19. The device of claim 16 wherein each revolute joint comprises a gear reduction mechanism.
20. The device of claim 19 wherein the gear reduction mechanism comprises an axial helical spline mechanism.

21. The device of claim 19 wherein the gear reduction mechanism comprises a concentric helical spline mechanism.

22. The device of claim 19 wherein the gear reduction mechanism comprises
a left-hand helical spline;
a right-hand helical spline;
a thrust washer positioned between the right-hand helical spline and the left-hand helical spline;

a helical spool, wherein the helical spool slides within the right-hand helical spline and the left hand helical spline and is rotationally engaged to the right-hand helical spline and the left hand helical spline; and

a cap screw axially clamping together the left-hand helical spline, the right-hand helical spline, and the thrust washer and allowing for a fine adjustment of the reduction mechanism while the bone fragment attachment apparatus is engaged with a bone fragment.

23. The device of claim 19 wherein the gear reduction mechanism comprises:

- a knob adjuster;
- a drive shaft;
- a bearing supporting the drive shaft;
- an Oldham disk having a tongue that engages a slot on the drive shaft;
- a gear having a slot that engages a tongue on the Oldham disk;
- a cam; wherein the cam has a circular cross section having an axis that is eccentric from the axis of rotation and controls the radial alignment of the gear;
- a lock knob, wherein the cam is affixed to the lock knob and a movement of the lock knob causes a movement of the cam; and
- a housing including an internal gear teeth having the same pitch as the external gear teeth of the gear and the number of internal gear teeth of the housing exceeds the number of external gear teeth of the gear.

24. The device of claim 18, wherein the strut comprises a rack and the second compound movable joint comprises a pinion that allows the second compound movable joint to move along the rack of the strut.

25. The device of claim 16 wherein the bone fragment attachment device comprises a pin clamp and one or more pins.

26. A compound movable joint for a unilateral fixator comprising a first revolute joint with a first axis and a second revolute joint with a second axis.

27. The device of claim 26 wherein the first axis and the second axis are orthogonally opposed.

28. The device of claim 26 further comprising a gear reduction mechanism having an axial helical spline mechanism with a right-handed helical spline and a left-handed helical spline.

29. The device of claim 26 further comprising a gear reduction mechanism having a concentric helical spline mechanism.

30. The device of claim 28 wherein the axial helical spline mechanism comprises:

- a left-hand helical spline;
- a right-hand helical spline;
- a thrust washer positioned between the right-hand helical spline and the left-hand helical spline;
- a helical spool, wherein the helical spool slides within the right-hand helical spline and the left hand helical spline and is rotationally engaged to the right-hand helical spline and the left hand helical spline; and
- a cap screw axially clamping together the left-hand helical spline, the right-hand helical spline, and the thrust washer and allowing for a fine adjustment of the reduction mechanism while the bone fragment attachment apparatus is engaged with a bone fragment.

31. The device of claim 26 further comprising a gear reduction mechanism having:

- a knob adjuster;
- a drive shaft;
- a bearing supporting the drive shaft;
- an Oldham disk having a tongue that engages a slot on the drive shaft;
- a gear having a slot that engages a tongue on the Oldham disk;
- a cam; wherein the cam has a circular cross section having an axis that is eccentric from the axis of rotation and controls the radial alignment of the gear;
- a lock knob, wherein the cam is affixed to the lock knob and a movement of the lock knob causes a movement of the cam; and
- a housing, including an internal gear teeth having the same pitch as the external gear teeth of the gear and the number of internal gear teeth of the housing exceeds the number of external gear teeth of the gear.

32. The device of claim 26 further comprising a gear reduction mechanism having:

a shaft having a cylindrical spline;

a first roller bearing assembly and a second roller bearing assembly;

a worm gear normal to and offset from the first roller bearing assembly and the second roller bearing assembly;

a gear positioned on top of the first bearing assembly and the second bearing assembly and having the same axis of revolution as the first bearing assembly and the second bearing assembly and also having a first face spline on the external face of the gear;

a lock bushing having a second face spline wherein the first face spline of the gear and the second face spline mate and having a cylindrical spline on an inner diameter of the lock bushing that engages with the cylindrical spline on the shaft; and

a lock nut threaded onto the shaft that locks the gear to the shaft.

33. A strut for a unilateral fixator , wherein the strut assembly comprises:

a base strut; wherein the base strut further comprises a square key inserted into a milled slot and

an extension strut; wherein extension strut comprises a linear adjuster, a threaded rod and a Solid, threaded locking insert, wherein the linear adjuster is connected to the base strut and the threaded rod, the threaded rod is also connected to the solid, threaded locking insert which is connected to the extension strut, further wherein when the linear adjuster is rotated, the extension strut moves within the base strut.